Com S 321 **NAME:**[redacted]

Spring 2016 **Exam 1** **Class Code No.:** [redacted]

DO NOT OPEN THIS EXAM UNTIL INSTRUCTED TO DO SO

This is a closed-book, closed-notes exam. You are allowed to use calculators. Use the backs of pages or extra pages if needed.

Some useful formulas are given in the Appendix at the end of the exam.

Please write your answers neatly and legibly. Please stop writing when asked to do so.

Problem	Pts	Pts obtained
1	20	20
2	20	20
3	20	20
4	20	20
5	20	20
TOTAL	100	100

Good!

1. (20 points)

(a) (6 points) We wish to compare the performance of two different machines: M1 and M2. The following measurements have been made on these machines:

Program	Time on M1	Time on M2
1	10 secs	4 secs
2	4 secs	5 secs

Which machine is faster for each program and by what percent?

Program 1:

$$\frac{M1}{M2} = \frac{10}{4} \Rightarrow 2.5 = 1 + \frac{N}{100}$$

$$N = 150$$

6

$$\boxed{\text{M2 is faster by } 150\%}$$

Program 2:

$$\frac{M2}{M1} = \frac{5}{4} \Rightarrow 1.25 = 1 + \frac{N}{100}$$

$$N = 25$$

$$\boxed{\text{M1 is faster by } 25\%}$$

(b) (4 points) Consider the two machines and programs in Part (a). The following additional measurements are made:

Program	Instructions executed on M1	Instructions executed on M2
1	$240 * 10^6$	$160 * 10^6$

4

Find the instruction execution rate (instructions per second) for each machine when running Program 1.

M1 Instruction Execution Rate:

$$\frac{240 \cdot 10^6}{10} = \boxed{24{,}000{,}000}$$

M2 Instruction Execution Rate:

$$\frac{160 \cdot 10^6}{4} = \boxed{40{,}000{,}000}$$

(c) (5 points)

Consider a machine M with a clock rate of 800 MHz. The average number of clock cycles for each instruction class on machine M is as follows:

Class	CPI for this class
A	2
B	5
C	2
D	3

Give the peak MIPS rating of M. What classes of instructions are used in computing the peak MIPS rating?

5

$$MIPS = \frac{800 \cdot 10^6}{2 \cdot 10^6} = \boxed{400}$$

Class A or C can be used. Want to use the smallest CPI.

(d) (5 points)

Consider a machine with a MIPS rating of 600. If the Instruction Count of a program executing on this machine is 1,875 million, what is its execution time?

5

$MIPS = 600$

$IC = 1875 \cdot 10^6$

$$600 = \frac{1875 \cdot \cancel{10^6}}{T \cdot \cancel{10^6}} \Rightarrow T = \frac{1875}{600} = \boxed{3.125 s}$$

2. (20 points) You have a system that contains a special processor for doing floating-point operations. You have determined that 50% of your computations can use the floating-point processor. The floating-point processor is 40% faster than the regular processor (so its speedup is 1 + 40/100 = 1.4).

(a) What is the overall speedup achieved by using the floating-point processor?

$F = 0.5 \quad S = 1.4$

$$OS = \frac{1}{(1-0.5)+{0.5}/{1.4}} = \boxed{1.16667}$$

(b) In order to improve the overall speedup you are considering two options:

- Option 1: Modifying the compiler so that 60% of the computations can use the floating-point processor. Cost of this option is $48,000.
- Option 2: Modifying the floating-point processor so that it runs 100% faster than the regular processor (so its speedup is 1 + 100/100 = 2). Assume in this case that 40% of the computations can use the floating-point processor. Cost of this option is $55,000.

Which option (1 or 2) would you recommend? Justify your answer quantitatively by comparing the [Cost/Overall Speedup] ratio for each option.

Option 1: $F = 0.6 \quad \$ = 48{,}000$

$S = 1.4$

$$OS = \frac{1}{(1-0.6)+{0.6}/{1.4}} = 1.2069. \Rightarrow \frac{48000}{1.2069} = 39771$$

Option 2: $F = 0.4 \quad S = 2 \quad \$ = 55{,}000$

$$OS = \frac{1}{(1-0.4)+{0.4}/{2}} = 1.25 \Rightarrow \frac{55000}{1.25} = 44000.$$

20

Option 1 is best since its $\frac{\text{cost}}{\text{overall speedup}}$ is smaller than option 2's.

39771 < 44000.

3. (20 points)

You have a computer system that contains a special processor for doing floating-point operations. You have determined that 40% of the computations in your application program can use the floating-point processor. The speedup of the floating-point processor by itself is 15 (not to be confused with the overall speedup).

(5 points) (a) What is the overall speedup achieved by Amdahl's Law when the floating-point processor is used? $F = 0.4$ $S = 15$

$$OS = \frac{1}{(1-0.4)+\frac{0.4}{15}} = \boxed{1.59574}$$

(15 points) (b) Suppose now we determine that some more improvements can be made to the application program. Let F_1 denote the 40% fraction described above with a speedup, S_1, of 15. Let F_2 denote another 20% fraction of the application program which can be modified to have a speedup, S_2, of 10. Let F_3 denote a further 10% fraction of the application program which can be modified to have a speedup, S_3, of 5.

Write a formula for overall speedup using a generalized version of Amdahl's Law. Use only the variables F_1, F_2, F_3 and S_1, S_2, S_3 in your formula.

$$OS = \frac{1}{\left(1-(F_1+F_2+F_3)\right)+\left(\frac{F_1}{S_1}+\frac{F_2}{S_2}+\frac{F_3}{S_3}\right)}$$

Compute the overall speedup when all three improvements are made.

20

$$\frac{1}{\left(1-(0.4+0.2+0.1)\right)+\left(\frac{0.4}{15}+\frac{0.2}{10}+\frac{0.1}{5}\right)}$$

$$\boxed{= 2.7273}$$

4. (20 points) Suppose you have a load/store computer with the following instruction mix:

Operation	Frequency	No. of Clock cycles
ALU ops	40% −12%	1
Loads	20% −12%	3
Stores	15%	3
Branches	25%	~~4~~ 6
New	12%	1

(a) Compute the CPI for the above data. Show ALL your work.

(b) We observe that 30% of the ALU ops are paired with a load, and we propose to replace these ALU ops and their loads with a NEW instruction. The NEW instruction takes 1 clock cycle. With the NEW instruction added, branches take 6 clock cycles. Compute the CPI for the new version. Show ALL your work.

(c) If the new clock rate is 25% faster than before, which version is faster and by what percent? Justify your answer quantitatively by showing ALL your work.

a) $CPI_{old} = \underbrace{(0.4 \cdot 1)}_{ALU} + \underbrace{(0.2 \cdot 3)}_{Loads} + \underbrace{(0.15 \cdot 3)}_{Stores} + \underbrace{(0.25 \cdot 4)}_{Branches}$

$\boxed{= 2.45}$ ✓

b) $0.4 \cdot 0.3 = 0.12$ ✓

$CPI_{new} = ((0.4-0.12) \cdot 1 + (0.2-0.12) \cdot 3 + (0.15 \cdot 3) + (0.25 \cdot 6) + (0.12 \cdot 1)) / (1-0.12)$ ✓

$= \boxed{2.943}$ ✓

c) $CCT_{old} = 1.25 \cdot CCT_{new}$ ✓

$CPU_{New} = (1-0.12) IC \cdot 2.943 \cdot CCT_{new} = 2.58984$ ✓

$CPU_{old} = IC \cdot 2.45 \cdot (1.25 \cdot CCT_{New}) = 3.0625$ ✓

20

$\frac{3.0625}{2.58984} \Rightarrow 1.18251 = 1 + \frac{N}{100} \Rightarrow N = 18$ ✓

New version is 18% faster than old.

5. (20 points)
Consider a program P with the following mix of operations: 10% Floating point multiplications, 15% Floating point adds, 5% Floating point divides, and 70% integer instructions. This program is executed on two machines – one with floating point hardware (MFP) and one with no floating point hardware (MNFP). Both machines have a clock rate of 500 MHz. On the MNFP machine, the floating point instructions are emulated using integer instructions, each integer instruction taking 2 clock cycles. On MFP, the floating point operations require the following number of cycles:

Floating point Multiply	8 cycles	$(8 \cdot .1) +$
Floating point Add	4 cycles	$(4 \cdot .15) +$
Floating point Divide	25 cycles	$(25 \cdot 0.05) +$
Integer instructions	2 cycles	$(2 \cdot 0.7) = 4.05$

On MNFP, the number of integer instructions required to emulate the floating point operations is as follows:

Floating point Multiply	30 integer instructions
Floating point Add	15 integer instructions
Floating point Divide	50 integer instructions

(a) Find the MIPS rating for both MFP and MNFP.

$MIPS_{MNFP} = \dfrac{500 \cdot 10^6}{2 \cdot 10^6} = \boxed{250}$ ✓

$MIPS_{MFP} = \dfrac{500 \cdot 10^6}{4.05 \cdot 10^6} = \boxed{123.457}$

(b) If the MFP machine needs 400 million instructions for the program P, how many integer instructions are needed on the MNFP machine for the same program P?

$0.1 \cdot 400 \cdot 10^6 \cdot 30 + 0.15 \cdot 400 \cdot 10^6 \cdot 15 + 0.05 \cdot 400 \cdot 10^6 \cdot 50 + 0.7 \cdot 400 \cdot 10^6 = \boxed{3.38 \cdot 10^9}$ ✓

(c) What is the execution time in seconds for program P on MFP and MNFP, assuming the instruction count from part (b)?

$MFP = \dfrac{400 \cdot \cancel{10^6}}{123.457 \cdot \cancel{10^6}} \boxed{3.24\ s}$ ✓

20

$MNFP = \dfrac{3.38 \cdot 10^9}{250 \cdot 10^6} = \boxed{1.352 \cdot \cancel{10}\ s}$ ✓

Careless Mistake

$\times 10$

13.52 secs